

PATENT ABSTRACTS OF JAPAN

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(21)Application number : 09-224013 (71)Applicant : KOBE STEEL LTD

(22)Date of filing : 20.08.1997 (72)Inventor : AKARI KOUICHIROU

(54) WEAR RESISTANT MULTI-LAYER TYPE HARD COATING FILM

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a multi-layer hard coating film excellent in adhesion between a coating film and a base material and wear resistance even for a wear resistant multi-layer hard coating film formed to a tool base material surface.

SOLUTION: In the wear resistant multi-layer type hard coating film formed to a tool base material surface, coating films made of a chemical composition shown with two kinds of TiAlN of a low hardness and high hardness are alternately laminated, a low hardness TiAlN layer has a chemical composition shown by $0.1 \leq x \leq 0.4$ in $Ti_{1-x}Al_xN$, a high hardness TiAlN layer has a chemical composition shown by $0.4 \leq x \leq 0.75$ in $Ti_{1-x}Al_xN$.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]**[0001]**

[Field of the Invention] This invention relates to abrasion resistance multilayer mold hard-anodic-oxidation-coatings structure useful as a surface coating material of the machining tool used for processing of milling, cutting, piercing, etc.

[0002]

[Description of the Prior Art] When manufacturing high speed tool steel, cemented carbide tool steel, etc., it is the purpose which should be more excellent in engine performance, such as abrasion resistance, and forming in the front face of a tool base material the abrasion resistance coat which consists of nitrides and carbide, such as Ti, is performed. As an approach of forming an abrasion resistance coat in a base material front face, a CVD method (chemical vapor deposition) and PVD (physical vapor deposition) are known conventionally. However, by the former approach, since a base material is put to high temperature processing, there is a possibility that a base material property may deteriorate, and in the case of the tool by which importance is attached also to a base material property, the latter approach tends to be liked. The high frequency discharge plasma-CVD method which can carry out coating processing by the low temperature service comparatively, the reactant ion plating method, the sputtering method, etc. have come [then,] to be adopted.

[0003] As abrasion resistance coats, such as a tool, TiN and TiC by the ion plating method are used widely, and the outstanding TiN film of especially elevated-temperature oxidation resistance (thermal resistance) is put in practical use widely. That is, since TiN excels TiC in thermal resistance, it demonstrates the function to protect the tool rake face which carries out a temperature up with the temperature increase by plastic working and the frictional heat at the time of cutting from crater wear. However, since TiN is a low degree of hardness compared with TiC, to the flank wear generated in the flank which touches **-ed material, rather, it is brittle and the direction of TiC shows high endurance to flank wear.

[0004] Much more improvement in the speed of cutting speed is demanded, and since it is in the inclination which cutting conditions make severe more, it is impossible in recent years, to be able to finish responding to this request in conventional TiN coat extent which was described above. Then, as a coat in which thermal resistance and a degree of hardness were further excellent, coats, such as TiAlN by the ion plating method or the sputtering method, TiAlC, or TiAlCN, were proposed (JP,62-56565,A).

[0005] Since the above-mentioned PVD is the low-temperature coat method for having used the energy of ion, between a base material front face and a coat, the diffusion layer by heat which was seen in the CVD method does not exist. Therefore, as for the coat formed of PVD, it is common that adhesion is inferior compared with the coat formed by the CVD method. On the other hand, although the inclination which thick-film-izes a coat is recently seen from a viewpoint of improving abrasion resistance and planning life extension, the internal stress of a coat increases as it thick-film-izes, and a crack occurs in a coat, or film adhesion falls and it becomes the cause of coat exfoliation. In addition, although it is as

having mentioned above that the system (N (aluminum, Ti), C) coat is proposed as a high abrasion resistance coat which can be replaced with a TiN coat, since internal stress becomes high more than twice compared with a TiN coat, these coats form the thickness thinnest possible than the case where a TiN coat is formed, and are used. An improvement of a coat formation technique which can fully demonstrate the property which was [coat / system] especially (aluminum, Ti) (N, C) excellent from such a thing was desired.

[0006] Then, while being able to produce the film by the low temperature service comparatively paying attention to such a situation, the abrasion resistance multilayer mold hard anodic oxidation coatings which were excellent in adhesion or film reinforcement and were moreover excellent in the drag force to crater wear or flank wear were offered (JP,6-136514,A). The coat layer which consists of chemical composition this coat configuration is indicated to be by $TiCx N 1-x$ (however, $0 \leq x \leq 0.6$), The coat layer which consists of chemical composition shown adjoins by turns. ($Aly Ti1-y$) ($Nz C1-z$) (however, $0.56 \leq y \leq 0.75$, $0.6 \leq z \leq 1$) A four or more layer laminating is carried out, and it is formed in the tool base material front face all whose coat thickness is 0.6-12 micrometers.

[0007] The above-mentioned abrasion resistance hard anodic oxidation coatings did not have enough abrasion resistance by the following reasons. Namely, in a laminating with TiN (in the case of $x = 0$), the degree of hardness of a TiN layer and oxidation resistance run short. ($Nz C(Aly Ti1-y)1-z$) In the laminating with $TiCx N 1-x$ ($0 \leq x \leq 0.6$), since a degree of hardness was high, both carried out the knowledge of being because adhesion with a base material and the adhesion between two kinds of layers running short ($Nz C(Aly Ti1-y)1-z$).

[0008]

[Problem(s) to be Solved by the Invention] While this invention solves the above-mentioned trouble and excelling in the adhesion of a coat and a base material, it aims at offering the multilayer mold hard anodic oxidation coatings which were further excellent in abrasion resistance.

[0009]

[Means for Solving the Problem] Invention which could attain the above-mentioned purpose is abrasion resistance multilayer mold hard anodic oxidation coatings formed in a tool base material front face. The coat which consists of chemical composition shown by two kinds of TiAlN(s), a low degree of hardness and a high degree of hardness, adjoins by turns, and a laminating is carried out (claim 1). Said TiAlN layer of a low degree of hardness consists of chemical composition shown by $Ti1-x Alx N 0.1 \leq x \leq 0.4$. It is what the TiAlN layer of a high degree of hardness becomes from the chemical composition shown by $Ti1-x Alx N 0.4 < x \leq 0.75$ (claim 2). Said TiAlN layer of a low degree of hardness is formed under the conditions of substrate bias voltage-10--30V at the time of coating. It is the thing which it comes to form under the conditions whose TiAlN layer of a high degree of hardness is substrate bias voltage-50--150V (claim 3). They are the abrasion resistance multilayer mold hard anodic oxidation coatings said whose unit coat number of layers by which a laminating is carried out is ten or more layers and whose thickness ratios of said low degree-of-hardness layer and a high degree-of-hardness layer are 5:1 - 1:10 further (claim 4) (claim 5).

[0010] This invention dares insert small, a low degree of hardness, i.e., the internal stress of a coat, TiAlN into the TiAlN coat which shows a high degree of hardness very much, it is considering as a laminated structure, the internal stress as the whole coat is eased, and the adhesion of a coat and a base material is improved. Moreover, although the abrasion resistance improvement effect by the propagation being controlled is acquired by the coat layer which the crack generated on the coat surface like the conventional technique by considering as a laminated structure adjoins, since the coat which carries out especially a laminating consists of the same element configuration shown by TiAlN, it excels also in the adhesion between laminating coats very much, and the coat exfoliation between layers decreases.

[0011] Incidentally, TiAlN shows a high degree of hardness compared with TiN, and, generally a degree of hardness rises according to the increment in aluminum ratio. Then, compared with the TiAlN layer usually created, the TiAlN layer of the low degree of hardness in considering as a low aluminum presentation is formed. In order to demonstrate the effectiveness of this invention, it is desirable to be $0.1 \leq x \leq 0.4$ and to be more preferably referred to as $0.2 \leq x \leq 0.3$ in $Ti1-x Alx N$, as an aluminum

presentation of a low degree-of-hardness TiAlN layer. The effectiveness of aluminum addition is not acquired, and a degree of hardness becomes high too much in $x > 0.4$, and it stops acting as a low degree-of-hardness layer in $x < 0.1$.

[0012] Next, what is shown by $Ti_{1-x}Al_xN$ $0.4 < x \leq 0.75$ is required for the TiAlN layer of a high degree of hardness, and it is desirable to be more preferably referred to as $0.6 \leq x \leq 0.65$. In $x \leq 0.4$, as a result of not acting as a high degree-of-hardness layer and a coat layer presentation approximating $x > 0.75$ to AlN, sufficient degree of hardness is no longer obtained. Moreover, a structure part injury of the TiAlN layer of a low degree of hardness and a high degree of hardness is possible for the degree of hardness of the TiAlN film generally formed of ion plating or a spatter by knowing being influenced greatly and controlling bias voltage by substrate bias voltage at the time of coating.

[0013] As formation conditions for a low degree-of-hardness TiAlN layer, bias voltage (V_b) is suitable for $-30V \leq V_b \leq -10V$, and it is desirable to be more preferably referred to as $-20V \leq V_b \leq -10V$. The electrical-potential-difference impression stabilized in order to stop acting as a low degree-of-hardness layer and to approach the plasma potential of the arc discharge plasma in the case of $V_b > -10V$ is difficult, and on the $0V$ bias, since the effectiveness of ion plating is not acquired, the property of a coat gets worse $V_b < -30V$.

[0014] Moreover, $-100V \leq V_b \leq -50V$ are more preferably [suitably / making bias voltage into the range of $-150V \leq V_b \leq -50V$ / as formation conditions for a high degree-of-hardness TiAlN layer, and] desirable. It stops acting as a high degree-of-hardness layer, and a degree-of-hardness fall takes place again, and $V_b < -150V$ stop acting as a high degree-of-hardness layer in $V_b > -50V$. In addition, although bias voltage was changed to discontinuity at this example by the 1st layer (low degree-of-hardness layer) which carries out a laminating, and the 2nd layer (high degree-of-hardness layer), it is also possible to change gradually change of the bias voltage between the 1st layer and the 2nd layer by the time amount which has attached inclination.

[0015] Next, although the unit coat number of layers by which a laminating is carried out is ten or more layers, it is 20 or more layers more preferably, and a good property is not acquired by less than ten layers in this case. As for the thickness ratio (thickness ratio) of a low degree-of-hardness layer and a high degree-of-hardness layer, in this invention, 5:1-1:10 (preferably 2:1-1:5) are desirable. If it separates from 5:1 and the ratio of a low degree-of-hardness layer becomes high, the whole degree of hardness will fall and abrasion resistance will fall. Moreover, if the ratio of a high degree-of-hardness layer becomes high exceeding 1:10, the whole degree of hardness will become high too much, and the adhesion of a coat will fall.

[0016]

[Example]

The target and Ti0.5 aluminum0.5 of a presentation of $Ti_{1-x}Al_x$ ($0.1 \leq x \leq 0.4$) in at least two arc evaporation sources which were attached in the location which countered with the <example 1> cathode arc method ion plating system on both sides of the substrate table in which self-revolution is possible. The target of a presentation was incorporated and coating to an end mill (phi 10) steel [high-speed] was carried out.

[0017] In forming the multilayer mold hard anodic oxidation-coatings of this invention, a substrate is first heated for the vacuum chamber of equipment at a heater after evacuation to 5×10^{-5} to 5 or less Torrs. Then, arc discharge is generated in a gas-less ambient atmosphere or Ar gas ambient atmosphere, and spatter cleaning of the substrate by metal ion is performed. the time of cleaning -- $Ti_{1-x}Al_x$ ($0.1 \leq x \leq 0.4$) and Ti0.5 aluminum0.5 one of the targets -- one of the two or both -- coincidence may be made to discharge After cleaning termination and the inside of a chamber are made into nitrogen-gas-atmosphere mind, and they are $Ti_{1-x}Al_x$ ($0.1 \leq x \leq 0.4$) and Ti0.5 aluminum0.5. Arc discharge is started to coincidence with both targets. The typical conditions at the time of coating are as follows.

[0018]

A <coating condition> and nitrogen-gas-pressure force: 2 - 4×10^{-2} Torr (2×10^{-2} Torr -- experiment conditions)

- Arc current : 80-200A (100A -- experiment conditions)

- Bias voltage : -40--150V (-50V -- experiment conditions)

- Thickness : 2.5-3.0 micrometers (an example is also this range extent and they are those with dispersion)

If the target with which presentations differ is made to discharge to coincidence under the above-mentioned gas pressure conditions, rotating a substrate table, the TiAlN film of a presentation according to a target presentation will be formed ahead [each / target], and the multilayer mold hard anodic oxidation coatings to which the laminating of two kinds of TiAlN film with which presentations differ as a result was carried out by turns will be formed. The thickness of each class can be adjusted by changing the rotational frequency of a rotation substrate electrode holder, or adjusting the arc current passed at a target. Moreover, in order to increase the thickness of each class above to some extent, two kinds of targets may be made to discharge by turns.

[0019] About the end mill which had various TiAlN film formed of the above-mentioned approach, the cutting trial on the following conditions was performed and the amount of edge-of-a-blade section wear was measured.

<Cutting conditions> and **-ed material : SKD61 (HRC30)

- Cutting speed : 30 m/min and delivery : 0.07mm / cutting edge, and infeed : 1mm (radial), 15mm (shaft orientations)

- The cutting approach : the result of down cutting and an air blow cutting trial is shown in Table 1 with the lamination of each coat. In addition, what carried out the laminating of a TiAlN monolayer, and TiN and the TiAlN layer of the conventional technique for the comparison is shown in Table 1.

[0020]

[Table 1]

No	皮膜構成				刃先部磨耗量 (mm)	備考
	第1層組成	第2層組成	屢數	膜厚比		
1	Ti _{0.7} Al _{0.3} N	Ti _{0.5} Al _{0.5} N	14	1:1	0.088	実施例
2	Ti _{0.7} Al _{0.3} N	Ti _{0.5} Al _{0.5} N	28	1:1	0.071	"
3	Ti _{0.7} Al _{0.3} N	Ti _{0.5} Al _{0.5} N	43	1:1	0.072	"
4	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	1:1	0.089	"
5	Ti _{0.5} Al _{0.2} N	Ti _{0.5} Al _{0.5} N	28	1:1	0.073	"
6	Ti _{0.5} Al _{0.4} N	Ti _{0.5} Al _{0.5} N	28	1:1	0.085	"
7	Ti _{0.7} Al _{0.3} N	Ti _{0.5} Al _{0.5} N	28	4:1	0.085	"
8	Ti _{0.7} Al _{0.3} N	Ti _{0.5} Al _{0.5} N	28	2:1	0.075	"
9	Ti _{0.7} Al _{0.3} N	Ti _{0.5} Al _{0.5} N	28	1:2	0.073	"
10	Ti _{0.7} Al _{0.3} N	Ti _{0.5} Al _{0.5} N	28	1:5	0.075	"
11	Ti _{0.7} Al _{0.3} N	Ti _{0.5} Al _{0.5} N	28	1:10	0.080	"
12	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	5	1:1	0.105	比較例
13	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	6:1	0.102	"
14	Ti _{0.5} Al _{0.5} N	-	1	-	0.185	"
15	TiN	Ti _{0.5} Al _{0.5} N	28	1:1	0.132	"

[0021] (Evaluation) As compared with the example (No.1-11) of Table 1, and the example of a comparison (No.12-15) Example No.of comparison 12 have few number of layerses than the number of specification of this invention, and, as for example No.of comparison 13, the thickness ratio has separated from the specific ratio of this invention. Example No.of comparison 14 are a TiAlN film monolayer, example No.of comparison 15 are TiN and a TiAlN cascade screen, these all are inferior in the thing of the example of a comparison as compared with the amount of edge-of-a-blade section wear of an example (mm), and it has become clear that the property with the good thing of an example is acquired.

[0022] The laminating of the TiAlN film of a <example 2> low degree of hardness and a high degree of hardness is possible also by changing the bias voltage at the time of coating periodically. In this case,

the thickness of each class can be adjusted by the change in time amount or an arc current which holds bias voltage uniformly. As a target, it is one kind of Ti0.5 aluminum0.5. Using the target which consists of a presentation, a cutting trial on the same conditions as an example 1 is performed about the end mill in which various TiAlN film was formed, and the result of having measured the amount of edge-of-a-blade section wear is shown in Table 2. What carried out the laminating of a TiAlN monolayer, and TiN and the TiAlN layer of the conventional technique is shown as an example of a comparison. (as common as an example 1).

[0023]

[Table 2]

No.	皮膜構成				刃先部磨耗量 (mm)	備考
	第1層バイアス電圧	第2層バイアス電圧	層数	膜厚比		
1	-10V	-50V	28	1:1	0.084	実施例
2	-10V	-100V	28	1:1	0.083	"
3	-10V	-150V	28	1:1	0.088	"
4	-20V	-50V	28	1:1	0.086	"
5	-30V	-50V	28	1:1	0.090	"
6	-40V	-50V	28	1:1	0.120	比較例
7	0V	-50V	28	1:1	0.212	"
8	-50V	-	1	-	0.185	"
9	TiN	Ti _{0.5} Al _{0.5} N (バイアス-50V)	28	1:1	0.132	"

[0024] (Evaluation) As compared with the example (No.1-5) of Table 2, and the example of a comparison (No.6-9), compare example No. of comparison 6, No.7, and No.8. No.8 are the thing of a TiAlN film monolayer. any -- the 1st layer bias voltage -- the numeric value outside this invention specification -- it is -- especially -- said -- Example No. of comparison 9 are the thing of TiN and a TiAlN cascade screen, all of these examples of a comparison are inferior in the thing of the example of a comparison as compared with the amount of edge-of-a-blade section wear of an example, and it has become clear that the property with the good thing of an example is acquired.

[0025]

[Effect of the Invention] As mentioned above, while this invention was excellent in the adhesion of a base material, the multilayer mold hard anodic oxidation coatings which were very excellent in abrasion resistance were obtained.

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CLAIMS

[Claim(s)]

[Claim 1] Abrasion resistance multilayer mold hard anodic oxidation coatings which are the abrasion resistance multilayer mold hard anodic oxidation coatings formed in a tool base material front face, and are characterized by for the coat which consists of chemical composition shown by two kinds of TiAlN (s), a low degree of hardness and a high degree of hardness, having adjoined by turns, and a laminating being carried out.

[Claim 2] Abrasion resistance multilayer mold hard anodic oxidation coatings according to claim 1 which the TiAlN layer of a low degree of hardness becomes from the chemical composition shown by $Ti_{1-x}Al_xN$ $0.1 \leq x \leq 0.4$, and the TiAlN layer of a high degree of hardness becomes from the chemical composition shown by $Ti_{1-x}Al_xN$ $0.4 < x \leq 0.75$.

[Claim 3] Abrasion resistance multilayer mold hard anodic oxidation coatings according to claim 1 which the TiAlN layer of a low degree of hardness is formed under the conditions of substrate bias voltage-10--30V at the time of coating, and it comes to form under the conditions whose TiAlN layer of a high degree of hardness is substrate bias voltage-50--150V.

[Claim 4] Abrasion resistance multilayer mold hard anodic oxidation coatings according to claim 1 to 3 whose unit coat number of layers by which a laminating is carried out is ten or more layers.

[Claim 5] Abrasion resistance multilayer mold hard anodic oxidation coatings according to claim 1 to 3 whose thickness ratios of a low degree-of-hardness layer and a high degree-of-hardness layer are 5:1 - 1:10.

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(71)出願人 000001199

株式会社神戸製鋼所

兵庫県神戸市中央区脇浜町1丁目3番18号

(72)発明者 赤理 孝一郎

兵庫県高砂市荒井町新浜2丁目3番1号

株式会社神戸製鋼所高砂製作所内

(74)代理人 弁理士 安田 敏雄

(54)【発明の名称】耐磨耗性多層型硬質皮膜

(57)【要約】

【課題】 工具母材表面に形成された耐磨耗性多層型硬質皮膜であって皮膜と基材の密着性に優れるとともに、さらに耐磨耗性に優れた多層型硬質皮膜を提供する。

【解決手段】 工具母材表面に形成される耐磨耗性多層型硬質皮膜であって、低硬度及び高硬度の2種類のTiAINで示される化学組成からなる皮膜が交互に隣接して積層され、前記低硬度のTiAIN層がTi_{1-x}Al_xNにて0.1≤x≤0.4で示される化学組成からなり、高硬度のTiAIN層がTi_{1-x}Al_xNにて0.4<x≤0.75で示される化学組成からなる。

【特許請求の範囲】

【請求項1】 工具母材表面に形成される耐磨耗性多層型硬質皮膜であって、低硬度及び高硬度の2種類のTiAINで示される化学組成からなる皮膜が交互に隣接して積層されたことを特徴とする耐磨耗性多層型硬質皮膜。

【請求項2】 低硬度のTiAIN層がTi_{1-x}Al_xNにて0.1≤x≤0.4で示される化学組成からなり、高硬度のTiAIN層がTi_{1-x}Al_xNにて0.4<x≤0.75で示される化学組成からなる、請求項1記載の耐磨耗性多層型硬質皮膜。

【請求項3】 低硬度のTiAIN層が、コーティング時の基板バイアス電圧-10~-30Vの条件下で形成され、高硬度のTiAIN層が基板バイアス電圧-50~-150Vの条件下で形成されてなる請求項1記載の耐磨耗性多層型硬質皮膜。

【請求項4】 積層される単位皮膜層数が10層以上である、請求項1~3のいずれかに記載の耐磨耗性多層型硬質皮膜。

【請求項5】 低硬度層と高硬度層の厚さ比が5:1~1:10である、請求項1~3のいずれかに記載の耐磨耗性多層型硬質皮膜。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、フライス加工、切削加工、穿孔加工等の加工に使用される工作工具の表面コーティング材として有用な耐磨耗性多層型硬質皮膜構造に関するものである。

【0002】

【従来の技術】高速度工具鋼や超硬合金工具鋼等を製作する場合は、耐磨耗性等の性能をより優れたものとする目的で、工具基材の表面にTi等の窒化物や炭化物による耐磨耗性皮膜を形成することが行なわれている。母材表面に耐磨耗性皮膜を形成する方法としては、従来よりCVD法(化学的蒸着法)およびPVD法(物理的蒸着法)が知られている。しかし前者の方法では母材が高温処理に曝される為母材特性が劣化するおそれがあり、母材特性も重要視される工具の場合は後者の方法が好まれる傾向がある。そこで比較的低温条件でコーティング処理することのできる高周波放電プラズマCVD法、反応性イオンプレーティング法、スパッタリング法等が採用されるに至っている。

【0003】工具等の耐磨耗性皮膜としてはイオンプレーティング法によるTiNやTiCが汎用されており、特に高温耐酸化性(耐熱性)の優れたTiN膜が広く実用化されている。即ちTiNはTiCより耐熱性に優れている為、切削時の加工熱や摩擦熱によって昇温する工具すくい面をクレータ磨耗から保護する機能を発揮する。しかしTiNはTiCに比べて低硬度である為被削材と接する逃げ面に発生するフランク磨耗に対してはむ

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しろ脆弱であり、フランク磨耗に対してはTiCの方が高い耐久性を示す。

【0004】近年、切削速度の一層の高速化が要望されており、切削条件がより過酷化する傾向にある為、上記した様な従来のTiN皮膜程度ではこの要請に応えきれなくなっている。そこで耐熱性や硬度が更に優れた皮膜として、イオンプレーティング法やスパッタリング法によるTiAIN、TiAlC、或はTiAlCN等の皮膜が提案された(特開昭62-56565)。

【0005】上記のPVD法はイオンのエネルギーを利用した低温皮膜法であるので、母材表面と皮膜間には、CVD法において見られた様な熱による拡散層は存在しない。従ってPVD法によって形成された皮膜は、CVD法によって形成された皮膜に比べて密着性が劣るのが一般的である。一方最近では耐磨耗性を改善して寿命延長を図るという観点から、皮膜を厚膜化する傾向が見られるが、厚膜化するにつれて皮膜の内部応力が増大し、皮膜にクラックが発生したり膜密着性が低下して皮膜剥離の原因になる。尚TiN皮膜に代わり得る高耐磨耗性皮膜として、(Al, Ti) (N, C) 系皮膜が提案されていることは上述した通りであるが、これらの皮膜はTiN皮膜に比べて内部応力が2倍以上も高くなるので、TiN皮膜を形成する場合よりもできるだけ薄い膜厚を形成して実用されている。こうしたことから、特に(Al, Ti) (N, C) 系皮膜等の優れた特性を十分に発揮し得る様な、皮膜形成技術の改善が望まれていた。

【0006】そこで、こうした事情に着目して比較的低温条件で製膜することができると共に、それにもかかわらず、密着性や膜強度に優れ、しかもクレータ磨耗やフランク磨耗に対する抵抗力の優れた耐磨耗性多層型硬質皮膜を提供した(特開平6-136514)。この皮膜構成はTiC_{1-x}N_x(但し、0≤x≤0.6)で示される化学組成からなる皮膜層と、(Al, Ti_{1-x})_y(N, C_{1-y})_z(但し、0.56≤y≤0.75, 0.6≤z≤1)で示される化学組成からなる皮膜層が交互に隣接して、4層以上積層され、かつ全皮膜層厚が0.6~1.2μmである、工具母材表面に形成されるというものである。

【0007】上記の耐磨耗性硬質皮膜は、以下の理由により耐磨耗性が十分ではなかった。即ち、TiN(x=0の場合)と(Al, Ti_{1-x})_y(N, C_{1-y})_zとの積層ではTiN層部の硬度及び耐酸化性が不足し、TiC_{1-x}N_x(0≤x≤0.6)と(Al, Ti_{1-x})_y(N, C_{1-y})_zとの積層ではどちらも硬度が高い為、基材との密着性や2種類の層間の密着性が不足することが原因であることを知見した。

【0008】

【発明が解決しようとする課題】本発明は上記の問題点を解決し、皮膜と基材の密着性に優れるとともに、さら

に耐磨耗性に優れた多層型硬質皮膜を提供することを目的とするものである。

【0009】

【課題を解決するための手段】上記目的を達成し得た発明とは、工具母材表面に形成される耐磨耗性多層型硬質皮膜であって、低硬度及び高硬度の2種類のTiAINで示される化学組成からなる皮膜が交互に隣接して積層されたものであり（請求項1）、前記低硬度のTiAIN層がTi_{1-x}A_xNにて0.1≤x≤0.4で示される化学組成からなり、高硬度のTiAIN層がTi_{1-x}A_xNにて0.4<x≤0.75で示される化学組成からなるものであり（請求項2）、前記低硬度のTiAIN層が、コーティング時の基板バイアス電圧-10~-30Vの条件下で形成され、高硬度のTiAIN層が基板バイアス電圧-50~-150Vの条件下で形成されてなるものであり（請求項3）、前記積層される単位皮膜層数が10層以上であるものであり（請求項4）、更に前記低硬度層と高硬度層の厚さ比が5:1~1:10である耐磨耗性多層型硬質皮膜である（請求項5）。

【0010】本発明は、非常に高硬度を示すTiAIN皮膜に、あえて低硬度、すなわち皮膜の内部応力の小さいTiAINをはさみ、積層構造とすることで、皮膜全体としての内部応力を緩和し、皮膜と基材の密着性が改善される。また、積層構造とすることで、従来技術同様に皮膜表層で発生したクラックが、隣接する皮膜層によって、その伝播が抑制されることによる耐磨耗性改善効果が得られるが、特に積層する皮膜がTiAINで示される同一の元素構成からなるため、積層皮膜間の密着性にも非常に優れ、層間での皮膜剥離が減少する。

【0011】因みにTiAINはTiNに比べて高硬度を示し、一般にAl比率の増加に従って硬度が上昇する。そこで通常作成されるTiAIN層に比べ、低Al組成とすることで低硬度のTiAIN層が形成される。本発明の効果を發揮させるためには低硬度TiAIN層のAl組成としてはTi_{1-x}A_xNにて0.1≤x≤0.4であり、より好ましくは0.2≤x≤0.3となるのが望ましい。x<0.1ではAl添加の効果が得られず、また、x>0.4では硬度が高くなりすぎ、低硬度層として作用しなくなる。

【0012】次に高硬度のTiAIN層は、Ti_{1-x}A_xNにて0.4<x≤0.75で示されるものが必要であり、より好ましくは0.6≤x≤0.65とするのが望ましい。x≤0.4では高硬度層として作用せず、また、x>0.75でも皮膜層組成がAlNに近似してくる結果、十分な硬度が得られなくなる。また、一般にイオンプレーティングやスパッタによって形成されるTiAIN膜の硬度はコーティング時の基板バイアス電圧によって大きく影響されることが知られており、バイアス電圧を制御することにより低硬度と高硬度のTiAIN

50 4 N層の作り分けが可能である。

【0013】低硬度TiAIN層の形成条件としてはバイアス電圧(Vb)が、-30V≤Vb≤-10Vが適当であり、より好ましくは-20V≤Vb≤-10Vとするのが望ましい。Vb<-30Vでは低硬度層として作用しなくなり、またVb>-10Vの場合はアーク放電プラズマのプラズマ電位に近づくために安定した電圧印加が難しく、また、0Vバイアスではイオンプレーティングの効果が得られないため皮膜の特性が悪化する。

【0014】また高硬度TiAIN層の形成条件としては、バイアス電圧を-150V≤Vb≤-50Vの範囲とするのが適当であり、より好ましくは-100V≤Vb≤-50が望ましい。Vb>-50Vでは高硬度層として作用しなくなり、またVb<-150Vでも再度硬度低下が起り、高硬度層として作用しなくなる。尚、本実施例では積層する第1層（低硬度層）と第2層（高硬度層）でバイアス電圧を不連続に変化させたが、第1層と第2層の間でのバイアス電圧の変化を勾配を付けてある時間で徐々に変化させることも可能である。

【0015】次に積層される単位皮膜層数が10層以上であるが、より好ましくは20層以上であり、この際10層未満では良好な特性が得られない。本発明では低硬度層と高硬度層の厚さ比（膜厚比）は5:1~1:10（より好ましくは2:1~1:5）が望ましい。5:1より外れて低硬度層の比率が高くなると全体の硬度が低下して耐磨耗性が低下する。また、1:10を越えて高硬度層の比率が高くなると、全体の硬度が高くなりすぎて皮膜の密着性が低下する。

【0016】

【実施例】

<実施例1>陰極アーク方式イオンプレーティング装置にて、自公転可能な基板テーブルを挟んで対向した位置に取り付けられた少なくとも2つのアーク蒸発源に、Ti_{1-x}A_x（0.1≤x≤0.4）の組成のターゲットとTi_{0.5}A_{0.5}の組成のターゲットを組み込み、高速度鋼製エンドミル（φ10）へのコーティングを実施した。

【0017】本発明の多層型硬質皮膜を形成するにあたっては、まず、装置の真空チャンバを5×10⁻⁶Torr以下まで真空排気後、ヒータによって基板の加熱を行う。その後、ガス無し窒素気中またはArガス充満気中にてアーク放電を発生させ、メタルイオンによる基板のスパッタクリーニングを行う。クリーニング時はTi_{1-x}A_x（0.1≤x≤0.4）、Ti_{0.5}A_{0.5}ターゲットのどちらか片方または両方同時に放電させて良い。クリーニング終了後、チャンバ内を窒素充満にして、Ti_{1-x}A_x（0.1≤x≤0.4）、Ti_{0.5}A_{0.5}の両ターゲットにて同時にアーク放電を開始する。コーティング時の代表的な条件は下記の通りである。

【0018】

<コーティング条件>

- ・窒素ガス圧力 : $2 \sim 4 \times 10^{-4}$ Torr (2×10^{-4} Torr … 実験条件)
- ・アーク電流 : 80 ~ 200 A (100 A … 実験条件)
- ・バイアス電圧 : -40 ~ -150 V (-50 V … 実験条件)
- ・膜厚 : 2.5 ~ 3.0 μm (実施例もこの範囲程度でばらつき有り)

上記ガス圧条件下で、基板テーブルを回転させながら、組成の異なるターゲットを同時に放電させると、各々のターゲット前方でターゲット組成に応じた組成の TiA_{1-x}N 膜が形成され、結果的に組成の異なる 2 種類の TiA_{1-x}N 膜が交互に積層された多層型硬質皮膜が形成される。回転基板ホルダーの回転数を変化させたり、ターゲットに流すアーク電流を調整することにより、各層の膜厚を調整することができる。また、ある程度以上各層の厚みを増すためには、2 種類のターゲットを交互に放電させてもよい。

【0019】上記方法によって各種 TiA_{1-x}N 膜を形成されたエンドミルについて、下記条件での切削試験を行

い、刃先部磨耗量を測定した。

<切削条件>

- ・被削材 : SKD61 (HRC30)
 - ・切削速度 : 30 m/min
 - ・送り : 0.07 mm/刃
 - ・切込み : 1 mm (半径方向), 15 mm (軸方向)
 - ・切削方法: ダウンカット、エアブロー
- 切削試験の結果を各皮膜の層構成とともに表 1 に示す。尚、表 1 には比較のために TiN 単層、及び従来技術の TiN と TiA_{1-x}N 層を積層したものを示す。

【0020】

【表1】

No.	皮膜構成				刃先部磨耗量 (mm)	備考
	第1層組成	第2層組成	層数	膜厚比		
1	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	14	1:1	0.088	実施例
2	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	1:1	0.071	~
3	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	43	1:1	0.072	~
4	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	1:1	0.089	~
5	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	1:1	0.073	~
6	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	1:1	0.085	~
7	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	4:1	0.085	~
8	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	2:1	0.075	~
9	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	1:2	0.073	~
10	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	1:5	0.075	~
11	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	1:10	0.080	~
12	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	5	1:1	0.105	比較例
13	Ti _{0.5} Al _{0.5} N	Ti _{0.5} Al _{0.5} N	28	6:1	0.102	~
14	Ti _{0.5} Al _{0.5} N	-	1	-	0.185	~
15	TiN	Ti _{0.5} Al _{0.5} N	28	1:1	0.132	~

【0021】(評価) 表 1 の実施例 (No. 1 ~ 11) と比較例 (No. 12 ~ 15) と比較すると、比較例 No. 12 は層数が本発明の特定数より少なく、比較例 No. 13 は膜厚比が本発明の特定比を外れており、比較例 No. 14 は TiA_{1-x}N 膜単層であり、比較例 No. 15 は TiN と TiA_{1-x}N 積層膜であり、これらの何れも実施例の刃先部磨耗量 (mm) と比較すると、比較例のものが劣っており、実施例のものは良好な特性が得られていることが判明している。

【0022】<実施例 2> 低硬度と高硬度の TiA_{1-x}N 膜の積層は、コーティング時のバイアス電圧を周期的に

変化させることによっても可能である。この場合、各層の膜厚はバイアス電圧を一定に保持する時間やアーク電流の増減によって調節可能である。ターゲットとしては 1 種類の Ti_{0.5}Al_{0.5} の組成からなるターゲットを用いて、各種 TiA_{1-x}N 膜を形成したエンドミルについて、実施例 1 と同じ条件での切削試験を行い、刃先部磨耗量を測定した結果を表 2 に示す。比較例として TiA_{1-x}N 単層、及び従来技術の TiN と TiA_{1-x}N 層を積層したものも示す。(実施例 1 と共通)。

【0023】

【表2】

No.	皮膜構成				刃先部磨耗量 (mm)	備考
	第1層バイアス電圧	第2層バイアス電圧	層数	膜厚比		
1	-10V	-50V	28	1:1	0.084	実施例
2	-10V	-100V	28	1:1	0.089	~
3	-10V	-150V	28	1:1	0.088	~
4	-20V	-50V	28	1:1	0.086	~
5	-30V	-50V	28	1:1	0.080	~
6	-40V	-50V	28	1:1	0.120	比較例
7	0V	-50V	28	1:1	0.212	~
8	-50V	-	1	-	0.185	~
9	TiN	Ti _x Al _{1-x} N (バイアス-50V)	28	1:1	0.132	~

【0024】(評価) 表2の実施例(No. 1~5)と比較例(No. 6~9)と比較すると比較例No. 6, No. 7, No. 8を比較をする、いずれも第1層バイアス電圧は本発明特定外数値であり特に同No. 8はTiAIN膜単層のものであり、比較例No. 9はTiNとTiAIN積層膜のものであり、これらの比較例の何れも実施例の刃先部磨耗量と比較すると、比較例のもの

が劣っており、実施例のものは良好な特性が得られていることが判明している。

【0025】

【発明の効果】以上のように本発明は基材の密着性に優れるとともに耐磨耗性に非常に優れた多層型硬質皮膜が得られた。